SOME FACTORS AFFECTING WATER ABSORPTION AND GERMINATION OF SEED CORN

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY George Harlan Dungan

ENTITLED Some Factors Affecting Water Absorption and Germination of Seed Corn

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SOME FACTORS AFFECTING WATER ABSORPTION

AND GERMINATION OF SEED CORN.

I. Introduction

Agricultural Experiment Stations and teachers of Agriculture throughout the corn belt are quite unanimous in their advice to the farmer concerning the selection and care of seed corn. The man on the farm is urged to harvest seed corn after while it is in the dent stage, before the first killing frost, and to store it under conditions that insure rapid curing. During the curing process the temperature must be controlled so that it will not fall to or below the freezing point; and provision must be made for proper ventilating facilities that will allow a rapid and effective circulation of air. After the moisture in the corn has been reduced to 12 or 14 per cent, the manner of storage is immaterial so long as the ears are protected from direct exposure to the weather. Just how long it will take for corn to reach a moisture content of 12 to 14 per cent is difficult for the farmer to determine. To be sure of complete curing he has been usually leaving his corn in the curing house unduly long and thus reducing the moisture content below 12 or 14 per cent. This continued curing no doubt, injures the grain as seed corn.

One of the topics for the present investigation is to find the effect that time of harvesting and thoroughness of drying has on the grain used for seed.

It has been long understood that the physiological activity in seeds is controlled to a great degree by the moisture in them. The quantity of water present in the seed during the dormant or storage period that will give the best growth and yield in the field has never been definitely worked out. The federal system of grading corn, promulgated in July 1916, has placed the most desirable moisture content of corn for safe keeping in storage at 14 per cent or below. The grading of corn involves a determination of test weight per bushel, per cent water contained in the sample, damaged corn which includes moldy kernels, heat damaged grains, etc. and foreign material and cracked corn. Water in corn is the most detrimental factor to its safe preservation in storage. It lowers the specific gravity of the corn and tends to contribute to the conditions that develop mustiness and heat damage. The only factor into which water does not enter in grade determination is foreign material and cracked corn. On the other hand, the absorption of water is the initial process in germination and growth. This report presents what was learned in the laboratory concerning the rapidity of water imbibition and speed of germination when corn of various initial moisture contents

was used.

Many farmers have observed that some types and varieties of corn sprout sooner in the field than others. This problem includes a study of two different types of corn and corn of the same variety but having different chemical composition.

It has been reported that the practice of soaking corn in water previous to planting is advantageous, especially if the planting is done late. Some trials were made to get some information on this question.

II. Literature

Kiesselbach and Ratcliff[1] report that from the standpoint of autumn freezes corn containing from 15 to 20 per cent of moisture is safe; and corn with 10 to 14 per cent of moisture will stand the most severe winter temperatures without injury to its germinative power. The fatal minimum moisture content of protoplasm is fixed by Ewart[2] at two or three per cent.

Water absorption by seeds is the first step in their germination. Atkins[3] in his imbibition studies working with beans and peas noted that the rate at which distilled water is taken up is no greater than that at which salt solutions are absorbed. Seeds placed in normal sulphuric acid, decinormal iodine, decinormal sodium chloride produced no concentration of these solutions. This was taken to prove that there is no semipermeable membrane in bean seed until germination begins when the

cell protoplasm acts as such, and that there is no difference in absorption between living and dead seeds until after germination when the protoplasmic membrane is formed. Brown and Worley[4] worked with barley grains and made water absorption studies at three different temperatures. They concluded that the velocity with which the water is absorbed by the seed is almost exactly an exponential function of the temperature. This is explained by presuming that cold water contains a relatively high proportion of "hydrone" $(O\,H_2)_2$ which upon being warmed breaks down into the simpler molecules. It would appear that only these simpler molecules are directly assimilated by the seeds or transmitted by the differential septum. Shull[5] states that it is his conviction after a number of years of experience with absorption phenomena, that absorption is a complex process dependent on a number of factors, some of which may be external, but many of which are internal. His work with Xanthium seeds and split peas indicates that absorption is both chemical and a physical process that is not entirely dependent upon temperature.

Soaking seeds previous to planting often hastens germination. Increased crop yields have been reported as the result of swelling seeds in water.[6] Recently Braun[8] has shown that the presoak method of seed treatment is an effective means of preventing seed injury due to chemical disinfectants and that this also increases germicidal efficiency.

The soaking of seed prior to planting never has had a wide practical application. However, when more is learned concerning the relation of temperature during early growth and later development, it may be profitable to swell seeds at the temperature found most desirable for maximum production. Walster's[9] work with Oderbrucher barley grown in sand cultures maintained at 15 degrees and 20 degrees centigrade is suggestive in this connection. The plants growing at the lower temperature were much more upright in growth habit, produced a greater proportion of culm to leaf, a greater proportion of skeleton material in the leaf and a greater degree of lignification of connective tissues in both leaf and culm.

III. Materials and Methods

The corn used was largely of the Reid's Yellow Dent variety having medium rough indentation. It conformed very closely to the type that was considered as standard by the Illinois Corn Growers Association prior to the adoption of the Utility Score Card in January, 1921. Part of this corn came from Professor J. G. Mosier's farm, south of Urbana, and part of it was produced on the Agronomy South Farm of the Agricultural Experiment Station.

Part of the corn was harvested at three different stages of its development; viz., milk stage, dent stage, and mature stage. Corn was considered to be in the milk stage when the content of the kernels had changed from its earlier watery form to a milky liquid having the con-

sistency of cream. This point in the development of the grain of corn was practically the same as that desired by users of roasting ears or cut corn for the table. In the dent stage development had progressed until the internal composition of the kernel had the consistency of dough and the crown of the grain had a small dimple dent. The husks were brown and dry, and the stalks were still green. Farmers are commonly advised to harvest their seed corn when it is in this period of its development. The mature samples were harvested at the time the corn was dry enough to begin cribbing. The kernels were completely dented and dry, and the ears contained approximately 20 per cent of water. The ears were taken to the greenhouse and allowed to dry at room temperature. During the winter after all the corn had reached an approximately uniform moisture content, imbibition and germination studies were made at a number of constant temperatures.

For the investigation on the influence of quantity of initial moisture on the speed of water absorption and vigor of germination, corn was taken directly from a crib. Ears were chosen on the basis of moisture content as determined by handling and visual appearance, and grouped into classes. Each class was shelled separately and thoroughly mixed forming a composite sample. A moisture determination was then made by the Brown -Duvel Moisture Tester Apparatus. It was planned to obtain composite samples of corn representing all grades from 1 to Sample inclusive. The Federal Grades in respect to moisture are

as follows:

Grade designation		Maximum moisture content
Grade	1	14 %
Grade	2	15.5
Grade	3	17.5
Grade	4	19.5
Grade	5	21.5
Grade	6	23
Grade	Sample	More than 23%

Each grade of corn was then poured into a separate mason jar and carefully sealed to prevent further desiccation. Imbibition studies were made as soon as practicable to avoid any deterioration of the corn in the sealed jars. However, some of the grades containing large quantities of water fermented and rapidly molded. Because of this rapid deterioration in storage it was deemed advisable to collect the samples of high moisture content as they were used.

Four ears each of Illinois High Protein, Illinois Low Protein, Illinois High Oil and Illinois Low Oil were obtained from the one year old seed stock of the Plant Breeding Division. Each ear of the high and low protein corn had been analyzed chemically and the data giving the amount of protein were furnished. The oil percentage was also known for every ear of the high and low oil types. The corn from these ears was studied both from the standpoint of rate of imbibition and rapidity and vigor of ger-

mination.

The seed that was used in the investigation of the effect of presoaking on the growth and yield of corn, was obtained from James R. Holbert, Bloomington, Illinois. It consisted of diseased and disease-free corn of Reid's Yellow Dent and Funk's Ninety Day varieties. Its diseased condition and freedom from disease had been determined by Mr. Holbert in germination tests on his neutral base or saw dust lime germinator.

In the imbibition studies a definite number of grains (either 25 or 50) were counted out and carefully weighed to within one centigram. The weighed corn was then poured into jelly glass jars. Two samples were prepared for each of six temperature chambers. These chambers were maintained at constant temperature - not varying as much as one-half a degree centigrade day or night. The temperatures used were 5 degrees, 10 degrees, 15 degrees, 20 degrees, 25 degrees, and 30 degrees centigrade. When the corn was placed into the temperature chambers it was covered with distilled water which had the same temperature as the chambers. At the end of the test the water was drained off and the corn dumped onto a dry absorbent towel. A corner of the towel was folded over the corn and rubbed hurriedly for a few seconds. The corn was then turned onto a second dry towel which was also folded over the kernels and rubbed until all superficial moisture on the grains was removed. The weight of the kernels was then obtained. Most of the imbibition determinations covered a twenty-four hour period,

but there was one series which was dried and weighed hourly for twenty-four hours. In order to make the soaking periods the same for all samples, new samples for the next day's work were put into the chamber as the ones to be dried and weighed were taken out. Water absorption calculations were made with the weight of water-free corn as the basis. Germination studies were made on plaster of Paris blocks. Slabs of plaster of Paris two inches thick and eight inches square were laid in galvanized iron pans. Water was poured over these until it came within approximately one-eighth inch of the top of the blocks. Grains of corn were then laid germs up on the plaster of Paris slabs. The cover was placed over the pan which was set into the temperature chamber. By this method when the lid was removed from the pan, every step in the germination process was easily visible.

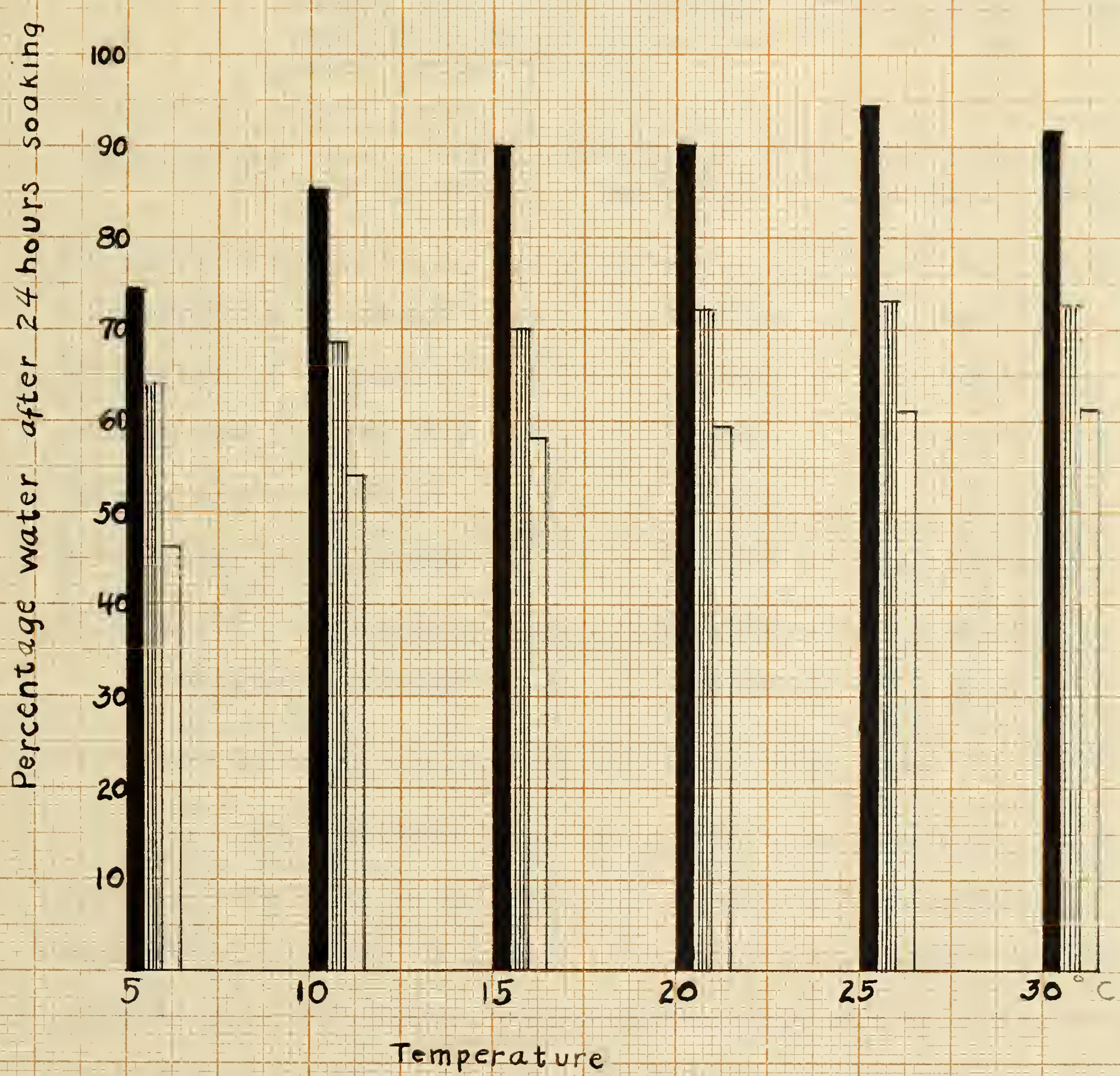
IV. Results.

Influence of Stage of Harvesting Corn on Its Water Absorption and Germination

The corn that was harvested at different stages in its development had approximately reached the same moisture content when the imbibition studies were made. The milk stage corn had 9.5% of water. The dent stage corn contained 10.7% and the completely mature grains 10.3%. The average weight of the kernels showed very striking differences. The early picked corn weighed approximately one half as much as the mature corn. Of 300 kernels of corn the average weight per grain harvested in the milk, dent, and ma-

Graph I.

Imbibition in "Milk", "Dent", and "Mature" Corn



Solid bar - "Milk" corn
Broken bar - "Dent" corn
Open bar - "Mature" corn

ture stages was .163, .268, and .320 grams, respectively. The amount of water absorbed in a twenty-four hour period by each lot of corn appears below based on the weight of water-free corn:

Table I. Water imbibed by corn harvested at 3 different stages of maturity during a period of 24 hours soaking in water maintained at 6 different constant temperatures.

Temperature	Water imbibed by corn harvested in		
	Milk stage	Well dented stage	Mature stage
5 degrees C	74.130	64.055	46.275
10 degrees C	85.160	68.710	53.970
15 degrees C	89.905	70.025	57.975
20 degrees C	90.075	71.780	59.255
25 degrees C	94.385	72.900	60.930
30 degrees C	91.465	72.565	61.070
Average	87.520	70.006	56.589

It is evident that early harvesting of corn influences the rate of water intake. Seemingly the maximum capacity for water is higher in immaturely picked corn than in that gathered later. This is probably due to the greater quantity of sugars in the earlier harvested grain. The "milk" and "dent" corn absorbed slightly less water at 30 degrees centigrade than at 25 degrees centigrade whereas the mature corn increased its water content at 30 degrees centigrade. The increase in water absorption for each 5 degree rise in temperature is much more clearly shown in

graph I than in the table.

Duplicate germination tests of 50 grains each were made of each sample of corn on plaster of Paris blocks at 15, 20, 25 and 30 degrees centigrade. Observations were made daily, and records of the progress of seedling development taken. The grains that had sent out a radicle only, were counted separately from those that had produced both a radicle and plumule. Table II summarizes the information collected in these tests. The columns headed "r" give the radicles only, while "r p" includes both the radicles and plumules.

Table II. The Germination of corn harvested at three different dates and germinated at four different constant temperatures.

Temperature	Corn used	Average percentage germination in												
		2 days		3 days		4 days		5 days		6 days		18 days		Per cent vitality
		r	rp	r	rp	r	rp	r	rp	r	rp	r	rp	
15°	Milk	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dent	0	0	3	0	7	0	-	-	-	-	-	-	7
	Mature	0	0	0	0	0	0	0	0	0	0	0	0	0
20°	Milk	9	0	23	1	69	11	43	37	29	63	-	-	92
	Dent	10	1	17	3	34	34	30	49	17	75	-	-	92
	Mature	1	1	10	12	36	26	22	46	11	83	-	-	94
25°	Milk	17	0	35	4	48	32	24	62	22	66	-	-	88
	Dent	23	1	33	7	28	62	18	78	9	88	-	-	97
	Mature	3	1	27	3	35	58	4	91	4	93	-	-	97
30°	Milk	36	7	39	25	24	66	-	-	-	-	-	-	90
	Dent	29	9	30	32	20	73	-	-	-	-	-	-	93
	Mature	27	0	36	20	15	81	-	-	-	-	-	-	96

The figures presented suggest that even though extremely early harvested corn absorbs water quickly and in large quantities the speed of germination during the first three days is only slightly greater than in "dent" corn. Later the "milk" corn is overtaken by the more mature kernels which at the end of the test surpass it in vitality. This lower vitality expressed in germinational vigor may be explained on the basis that the immature corn had not received sufficient or properly balanced translocated material from the parent plant before it was harvested. The dent corn is more rapid in germination than the mature corn, but it is surpassed in viability by the latter.

It may be noted that at 30 degrees C. the immature corn had produced 36 "r's" and 7 "r p's" in two days during which time the "dent" corn had sent out 29 "r's" and 9 "r p's" and the mature corn 27 "r's" and no "r p's". At the end of the third day the "dent" corn had developed 32 plumules as compared to 25 and 20 for the "milk" and "mature" corn, respectively. The close of the fourth day shows the "mature" corn to be much superior to either of the others and the "dent" corn much better than the "milk" sample. The same striking differences appear at the end of 6 days at temperatures of 20 and 25 degrees C, except that at 20 degrees the plumule production of the milk corn does not at any time equal that of that harvested later. This leads to the conclusion that low temperature favors root development and retards the growth of the shoot.

Effect of Initial Moisture in Corn on Its Water Absorption and Germination.

Five of the seven grades of corn were used in the studies of imbibition. The original moisture content of the samples and the quantity of water taken up during twenty-four hours at the six temperatures appears in Table III. The lower half of the table shows the amount of water that was absorbed over and above the moisture already present in the seed.

Table III. Imbibitional study of corn containing different amounts of initial moisture.

Grade	Percent moisture content	Percentage moisture in corn calculated on the basis of water-free corn after a 24 hour period of soaking in distilled water at -					
		5	10	15	20	25	30° C
One	13.9	34.30	45.69	46.49	49.51	52.34	55.03
Two	14.2	43.42	49.11	49.41	53.59	53.76	58.89
Four	18.3	42.96	48.28	50.12	54.30	55.87	60.38
Five	20.2	41.72	46.54	50.15	53.88	56.58	59.93
Sample	23.5	50.02	54.40	57.00	60.55	61.28	67.71
Grade	**Moisture content**	**Percentage moisture taken up by the corn during a 24 hour period at -**					
		5	10	15	20	25	30° C
One	13.9	21.40	31.79	32.59	35.61	38.44	41.13
Two	14.2	29.22	34.91	35.21	39.39	41.56	44.69
Four	18.3	24.66	29.98	31.82	36.00	37.57	42.08
Five	20.2	21.52	26.34	29.95	33.68	36.38	39.73
Sample	23.5	26.52	30.90	33.50	37.05	37.78	44.21

It is evident from a study of the above data that the natural moisture in corn is not the only factor or at least not the direct factor that influences the quantity of water absorbed. The elements that enter into the imbibitional process and bring about wide differences in amount of water taken up at 5 degrees are less potently operative at 30 degrees. The corn containing 14.2% initial moisture leads all of the samples in amount of water absorbed. This is followed by Sample grade, with grades one and four running close together. Grade five has taken on the smallest quantity of additional water of any one of the series.

For the germination phase of the problem on the influence of initial moisture on rapidity of seedling development, three samples of corn having a moisture content of 6.1, 12.6 and 19.2 per cent, respectively, were obtained. These were germinated at 10, 20, 25, and 30 degrees C.

Table IV. Germination tests of corn containing different amounts of moisture.

Case	Moisture Content of corn used	Average percentage germination at end of 2 days		3 days		4 days		5 days		6 days		7 days		8 days		18 days		Total % Vitality
		r	rp	r	rp	r	rp	r	rp	r	rp	r	rp	r	rp	r	rp	
10°	6.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	12.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	19.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	3	10
20°	6.1	0	0	0	0	0	0	0	0	7	0	28	3	45	7	1	95	96
	12.6	0	0	0	0	0	0	0	1	46	4	66	14	59	30	2	97	99
	19.2	0	0	0	0	2	0	12	1	33	3	30	9	27	18	3	77	80
25°	6.1	3	0	17	0	55	32	-	-	-	-	-	-	-	-	-	-	87
	12.6	44	0	73	12	20	80	-	-	-	-	-	-	-	-	-	-	100
	19.2	55	0	61	19	14	72	-	-	-	-	-	-	-	-	-	-	86
30°	6.1	91	0	29	63	-	-	-	-	-	-	-	-	-	-	-	-	92
	12.6	97	0	9	88	-	-	-	-	-	-	-	-	-	-	-	-	97
	19.2	85	0	12	73	-	-	-	-	-	-	-	-	-	-	-	-	85

At 20° after 5 days the "19.2 per cent" corn had produced 12 "r's" and 1 "r p", the "12.6 per cent" corn 8 "r's" and 1 "r p", and the "6.1 per cent" corn had not begun to germinate. This behavior would suggest that high initial moisture in corn will give rise to rapid germination. The advantage the more moist sample had is lost, however, at the close of the sixth day. The results obtained after 2½ days at 25 degrees are in accord with those cited above at 20 degrees. The third day at 25 degrees

shows 19, 12, and no "r p's" for the "19.2%" and "6.1%" corn, respectively. The order changes in favor of the "12.6%" corn on the fourth day. The readings have not been continued long enough to indicate whether the "r p" production would finally swing to the drier corn, but the data taken the eighteen day at 20 degrees suggest such a possibility. There is also some very good evidence brought out in this table to lead to the conclusion that corn containing as little as 6.1% moisture is too dry for strong 100 percent vitality, and that corn having as much moisture as 19.1 per cent is too moist for best germination, although the development of the embryos that are viable, is rapid.

Moisture in seeds is commonly considered the most influential factor in determining the life processes going on within them. It would seem that with "6.1%" corn desiccation had progressed so far that life activity was materially reduced making renewal of these functions tardy and in some of the seeds difficult or impossible. The "19.2%" corn has been carrying on rapid respiration for so long that it is weakened and many of the germs are dead. The initial germinative processes are rapid, but the value of this corn for seed purposes is not nearly as great as that of the "12.6%" corn.

Composition of the Corn Kernel and Its Water Absorption

Four ears of the Illinois High Oil, Illinois Low Oil, Illinois High Protein and the Illinois Low Protein

were obtained of Mr. Louis Hunter of the Plant Breeding Division. From the high and low oil ears three rows of kernels from each ear had been taken for an analytical determination of the percentage of oil. The high and low protein corn had been sampled similarly for protein determination. The results of these analyses show wide extremes in kernel composition.

Table V. Percentage of Protein and Oil in Ears of Extreme Types with respect to these Constituents.

Ear No.	Type	Moisture Content	Percentage Protein	Percentage Oil	Average
15	High Oil	8.14	-	9.51	
36	" "	6.84	-	9.11	(Oil)
41	" "	7.09	-	9.61	
91	" "	7.26	-	9.38	9.40
26	Low Oil	8.49	-	1.83	
33	" "	8.81	-	1.90	(Oil)
73	" "	8.19	-	1.82	
102	" "	10.04	-	1.73	1.82
19	High Protein	6.85	5.15	-	
26	" "	7.02	14.26	-	(Protein)
47	" "	5.87	15.90	-	
69	" "	7.26	15.56	-	15.29
3	Low Protein	7.00	6.50	-	
22	" "	7.35	5.90	-	(Protein)
25	" "	8.30	6.00	-	
96	" "	7.85	5.98	-	6.095

The high oil corn contained 5.16 times as much oil as the low oil strain, while the protein content of the high type was 2.18 times that of the low. Twenty-five kernels in duplicate from each ear were soaked in water for 24 hours. The results obtained appear below.

Table VI. Imbibition in Corn from Individual Ears of Special High and Low Oil, and High and Low Protein Corn.

Type	Ear No.	Percentage water in the corn after soaking in water at					
		5	10	15	20	25	30° C
High Oil	15	38.52	40.02	45.45	49.10	50.76	50.57
" "	36	32.76	38.00	44.65	46.53	47.90	50.63
" "	41	38.36	41.21	45.50	49.66	52.41	56.00
" "	91	34.17	37.85	45.14	48.91	50.33	53.47
Low Oil	26	40.66	42.08	45.54	50.67	52.69	54.19
" "	33	33.15	37.71	43.24	46.72	48.93	50.51
" "	73	30.65	33.64	41.08	43.68	45.06	47.59
" "	102	33.85	39.28	45.25	50.28	50.59	52.83
High Protein	19	28.82	31.33	35.84	41.58	43.47	45.47
" "	26	30.96	30.71	39.29	43.12	46.80	48.29
" "	47	26.82	30.01	35.01	41.47	44.20	46.05
" "	69	30.09	34.55	39.74	44.93	45.55	47.21
Low Protein	3	34.91	40.14	43.91	47.82	49.75	51.38
" "	22	36.02	39.21	46.07	50.48	55.79	58.64
" "	25	35.82	39.09	44.59	48.23	49.45	57.80
" "	96	37.39	39.59	44.98	48.68	52.78	53.82

Ears number 15 and 41 of the high oil series are consistently higher in water content than the others, with the single exception of ear number 91 at 30°C. Ear "36" is rather uniformly lower in water intake than the other three in this group. It is also slightly lower in oil content, and somewhat lower in original moisture, While the results are not conclusive, they are suggestive that slight increased quantities of oil in corn is associated with greater water absorption. Practically all the oil in corn is located in the germ region. High oil corn possesses a very large germ in proportion to endosperm. It is presumably the rapid intake of water by the large germs that gives the higher imbibitional curve for the high oil corn.

With the low oil corn, the correlation between original moisture content or slight variations in oil percentage, and quantity of water absorbed does not seem to be significant. The differences that appear at five degrees carry through uniformly with but few exceptions. The fluctuations between corn of so nearly the same composition in respect to oil must be due to unknown individual ear variations.

It will be noted that our ear number 26 which is more than one per cent lower in protein than its three companions, has absorbed slightly more water than the others. Ear number 47 which is highest in protein has imbibed the least amount of water at four of the six temperatures. High protein even when differences are very slight, appears to hinder water absorption. Since ear number 47 is the lowest

in original moisture content and the highest in protein composition it would seem that the presence of protein favors desiccation.

Low protein ear number 22 is the lowest in protein content and the highest in water content at four of the six temperatures. Ear number 3 is the highest in protein of any of the ears of the low protein group, and is the lowest in absorption in two-thirds of the trials.

In order to present more clearly the performances of each of the four groups of corn the data from the individual ears have been averaged and are shown in Table VII and Graph II.

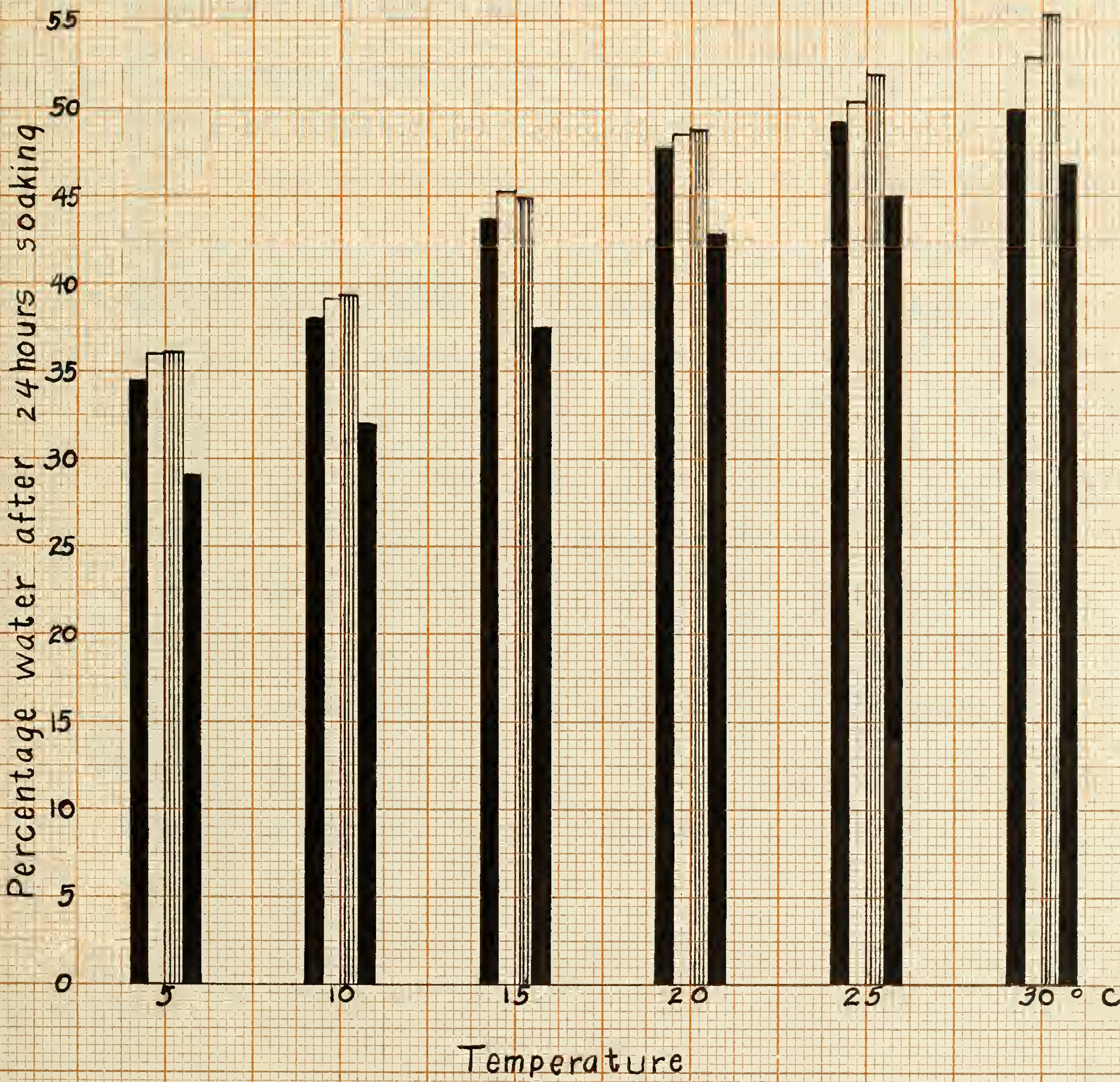
Table VII. Average of Imbibitional Data from High and Low Oil and High and Low Protein Corn.

Type	Percentage water in the corn after soaking in water at						Average
	5	10	15	20	25	30°C	
High Oil	35.95	39.27	45.19	44.55	50.35	52.92	45.37
Low Oil	34.58	38.18	43.78	47.84	49.29	50.03	43.95
High Protein	29.17	31.90	37.47	42.78	45.01	46.76	38.85
Low Protein	36.04	39.51	44.89	48.80	51.94	55.41	49.10

The low oil corn possesses a much larger proportion of endosperm than does the high oil strain. The starches and sugars of this part of the kernel take up water almost as rapidly as the unusually large germs of the high oil corn. In the high protein corn, the protein is carried largely in the aleurone layer and in the horny starch

Graph II.

Imbibition in High Oil, Low Oil, Low Protein and High Protein corn



First solid bar - High Oil corn
Open bar - Low Oil corn
Broken bar - Low Protein corn
Second solid bar - High Protein corn

around the outer walls of the endosperm. This serves as a semi-impervious layer around the soft starchy portion within, and protects the germ from contact with water except from one side. The low protein corn contains a much larger proportion of soft starch tissue with very little and often none of the horny tissue surrounding it. This permits ready intake of water.

The germination of this corn on plaster of Paris blocks at 20, 25, and 30° temperatures shows results somewhat different from those obtained in water absroption studies. The detailed notes concerning the germination appear below in Table VIII. The type of corn is indicated by the initial of the strain name as "L.O." for Low Oil, "H.P." for High Protein, etc. The percentage number of kernels that had produced radicles is indicated by "r"; both radicles and plumules by "r p"; seminal roots by "s r"; leaf emergence through the coleoptile by "le"; plumules that were produced without radicles by "p"; and the average length of the plumule in inches by "p l".

Table VIII. Germination of High and Low Oil and High and Low Protein Corn at 20, 25 and 30° C.

Time (Days)	Devel-op-ment	20°				25°				30°			
		LO	H O	L P	H P	L O	H O	L P	H P	L O	H O	L P	H P
2	r	0	0	0	0	0	0	3	0	0	6	0	0
3	r	0	0	0	0	0	24	70	75	37	31	58	68
	rp	0	0	0	0	0	12	3	3	3	46	20	18
	sr	0	0	0	0	0	6	3	0	0	30	3	3
4	r	0	0	0	0	49	27	40	18	45	0	48	18
	rp	0	0	0	0	0	73	58	82	37	94	45	83
	rs	0	0	0	0	0	45	28	50	25	86	25	73
5	r	0	0	0	0	63	0	8	0	11	0	20	0
	rp	0	0	0	0	20	100	93	100	69	94	80	100
	sr	0	0	0	0	6	97	95	90	60	94	73	98
6	r	0	0	0	0	26	0	0	0	3	3	18	0
	rp	0	0	0	0	49	100	100	100	80	91	80	100
	sr	0	0	0	0	40	100	100	100	91	94	73	100
	le	0	0	0	0	0	6	5	13	9	37	5	40
7	r	0	0	0	0	3	0	0	0	3	3	10	0
	rp	0	0	0	0	74	100	100	100	80	91	88	100
	sr	0	0	0	0	74	100	100	100	80	94	85	100
	le	0	0	0	0	3	30	45	83	31	74	33	80
8	r	0	3	10	0	3	0	0	0	3	3	5	0
	rp	0	0	0	0	74	100	100	100	83	91	93	100
	sr	0	0	0	0	74	100	100	100	80	94	85	100
	le	0	0	0	0	6	88	70	93	60	77	83	93
10	r	0	27	48	8	6	0	0	0	0	3	0	0
	rp	0	0	0	0	77	100	98	100	86	83	95	100
	sr	0	0	0	0	83	100	100	100	83	89	88	100
	le	0	0	0	0	40	97	90	95	74	80	75	100
	p	0	0	0	0	9	0	3	0	6	6	0	0
	pl(in.)	-	-	-	-	4.9	5.9	4.9	7.5	6.0	8.7	4.9	9.1
12	r	0	27	58	8								
	rp	0	0	5	0								
	sr	0	0	3	0								
	le	0	0	0	0								
18	r	6	58	50	38								
	rp	0	42	43	40								
	sr	0	12	13	8								
	le	0	0	5	0								
24	r	9	27	35	23								
	rp	0	67	60	50								
	sr	0	45	23	30								
	le	0	15	13	8								
	p	0	3	0	0								
	pl (in)	0	1.3	1.3	1.2								

It will be noted that the High Oil corn germinated more rapidly, had a higher total vitality, and produced plumules of greater length than that of the Low Oil type. This is particularly noticeable at 20 degrees. The difference in germination is much greater than would be suggested by the differences in water absorption of these two corns. However, since the germs and embryo of the Low Oil kernels are so small, it is reasonable to suppose that the vitality and vigor of this corn would be low.

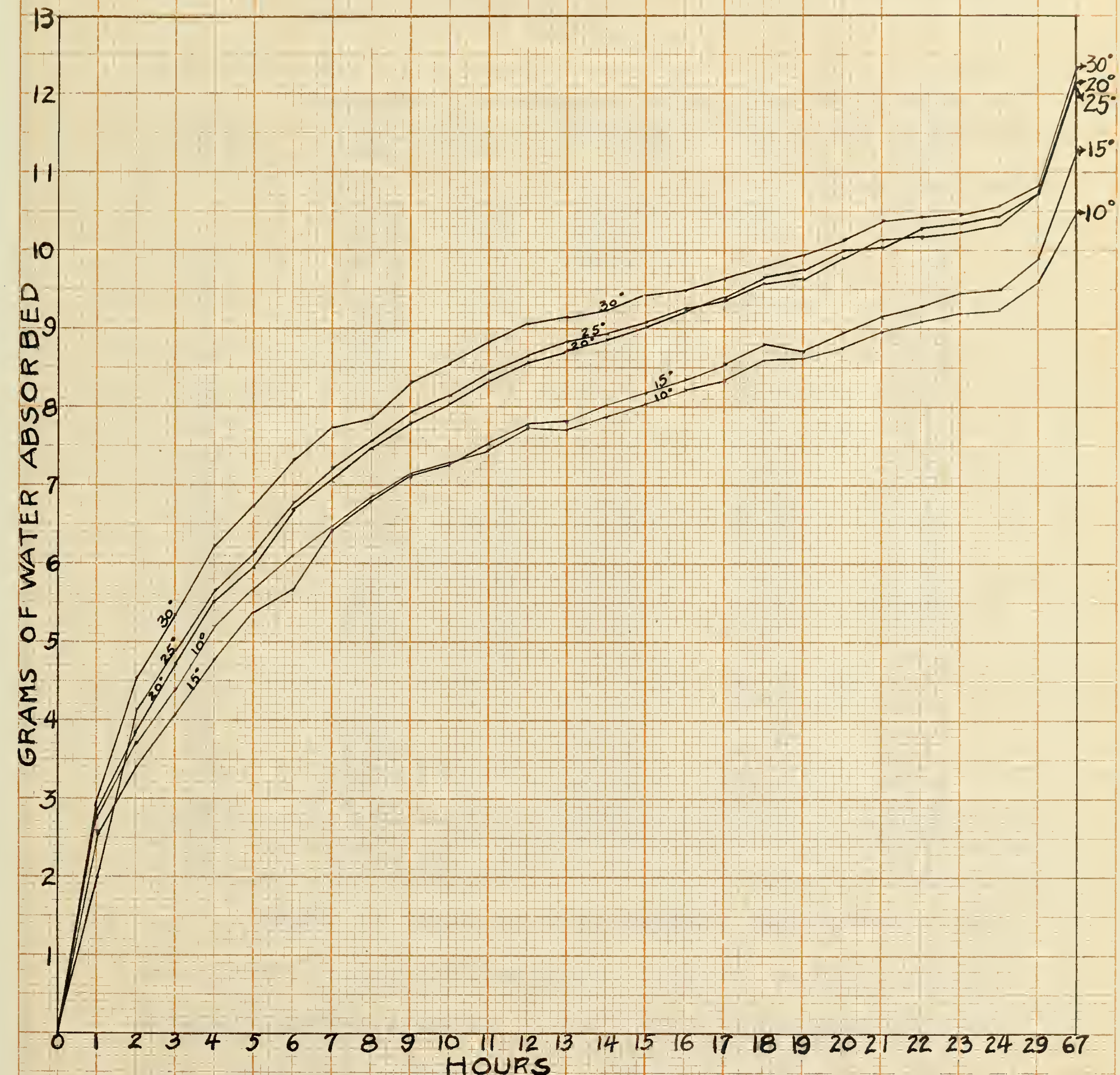
The Low Protein corn has produced more radicles in two days at 25 degrees than has the High Protein corn. At 20 degrees the Low Protein is ahead of the High Protein in every respect. The rapidity of germination and the speed of subsequent growth at 25 and 30 degrees is much greater, however, in the High Protein corn. The average length of the High Protein plumules is 86 per cent greater at 30 degrees and 53 per cent greater at 25 degrees than that of the Low Protein corn. Low Protein content is evidently a limiting factor in seedling development following germination.

Influence of Temperature on Water Absorption

The lack of harmony between water absorption and germination has suggested the need of some study on the rate of water intake by corn grain. And also since temperature is so fundamental to germination it was desired to see if this influence was due to reduction or increase in the absorption of water. Fifty grains of corn of the same composite lot were soaked in distilled water at five con-

Curve I.

Quantity of Water Absorbed by Fifty Kernels of Corn at Five Different Temperatures



stant temperatures and weighed every hour for 24 and then again at the end of 29 and 67 hours. The quantity of water taken up during each interval appears below in Table IX and in Curve I.

Table IX. Rate of water absorption by corn at five constant temperatures.

Time (Hours)	Increase in weight of fifty grains of corn as the result of soaking in distilled water at-				
	10°	15°	20°	25°	30°
	grams	grams	grams	grams	grams
1	2.76	2.53	2.83	2.00	2.58
2	3.72	3.41	3.83	4.14	4.54
3	4.41	4.07	4.72	4.90	5.34
4	5.22	4.79	5.50	5.66	6.23
5	5.67	5.39	5.92	6.15	6.71
6	6.11	5.68	6.68	6.80	7.32
7	6.49	6.42	7.04	7.22	7.73
8	6.86	6.79	7.45	7.57	7.83
10	7.29	7.27	8.04	8.16	8.54
11	7.47	7.52	8.33	8.46	8.84
12	7.71	7.77	8.57	8.67	9.05
13	7.70	7.80	8.73	8.83	9.13
14	7.88	8.01	8.86	8.93	9.21
15	8.06	8.18	9.01	9.08	9.43
16	8.22	8.37	9.23	9.25	9.48
17	8.34	8.53	9.39	9.37	9.62
18	8.60	8.81	9.65	9.58	9.80
19	8.61	8.70	9.74	9.65	9.91
20	8.76	8.96	10.00	9.91	10.13
21	8.98	9.15	10.02	10.14	10.39
22	9.09	9.29	10.28	10.18	10.41
23	9.19	9.47	10.35	10.25	10.46
24	9.24	9.50	10.44	10.31	10.58
29	9.59	9.90	10.75	10.76	10.81
67	10.89	11.28	12.13	12.14	12.32

Water is taken up very rapidly during the first few hours. After the tenth or eleventh hour the curve slightly flattens until the end of the twenty-first hour, when its upward climb is further reduced. The curves for all the temperatures run in the same general direction with only slight differences in angle. Curves for 10 and 15, and for 20 and 25 degrees are quite

noticeably paired. The wide differences in germination that have been brought about by temperature can hardly be accounted for by differences in water absorption. The corn at 10 degrees absorbed approximately the same amount of water in 24 hours as that at 30 degrees did in 12 hours. If water is the primary essential in germination, corn at 10 degrees should make as much growth in 10 days as that at 30 degrees does in 5 days. The germination data presented previously show that there are greater differences than these, occurring between 20 and 25 degrees.

Two Types and Two Varieties of Corn Soaked in Water at Five Constant Temperatures and for Four Different Periods and Planted in the Field for Performance Studies.

Field practice has indicated that two or three days in the growth of corn may be gained by soaking the seed in water for a time before planting. Director Russell of the Rothamsted Experiment Station is quoted[7] as saying in connection with an explanation for the frequent benefit obtained from treating seeds electrolytically that kiln dried barley, especially after steeping, will germinate more evenly and satisfactorily than will ordinary barley. This is particularly the case if the barley contains any amount of moisture over 14 or 15 per cent. The soaking of wheat and barley as a part of the treatment for the control of loose smut disease is a common practice.

Just how long the soaking should be continued, and at what temperature, has never been hinted at. Walster's[9]

work with barley has suggested the possibility that low temperature may be more desirable than high. Corn that had been germinated by Mr. J. R. Holbert, Pathologist, United States Department of Agriculture and classified into diseased and disease-free groups from the stand point of the corn rot diseases was chosen to be used in an experiment planned to furnish some information on the question of benefits from soaking seed corn. Moisture tests were made on each of the four corns with the following results:

Table X. Moisture Determination of Four Air dry Samples of Corn.

Variety	Disease condition	Per cent moisture
Funk's 90-Day	Disease-free	9.0
Funk's 90-Day	Diseased	9.2
Reid's Yellow Dent	Disease-free	10.8
Reid's Yellow Dent	Diseased	9.5

One hundred kernel samples of each of the above four types of corn were soaked for 12, 24, 36, and 48 hours respectively, at each of 10, 15, 20, 25, and 30° temperatures. Determinations were made of the percentage of water absorbed. These results appear in Table XI.

Table XI. Absorption by disease-free and diseased Funk's Ninety Day; and disease-free and diseased Reid's Yellow Dent Corn.

Time (Hours)	Corn	10	15	20	25	30
12	Funk's D.F.	32.08	35.52	37.14	38.32	45.76
	Funk's D.	34.93	39.68	42.83	44.67	46.86
	Reid's D.F.	34.99	36.90	40.45	42.43	44.36
	Reid's D.	36.58	40.39	45.24	44.90	47.21
24	Funk's D.F.	38.37	42.20	46.89	48.12	48.97
	Funk's D.	41.35	49.59	50.64	52.96	57.70
	Reid's D.F.	40.94	46.58	48.17	50.01	50.83
	Reid's D.	42.00	49.32	52.10	53.85	57.79
36	Funk's D. F.	42.94	47.31	50.45	52.50	31.14
	Funk's D.	46.57	53.21	53.87	57.54	61.00
	Reid's D. F.	44.51	50.27	50.44	56.33	55.30
	Reid's D.	47.34	53.91	53.45	38.61	61.62
48	Funk's D.F.	46.54	49.80	51.87	55.24	57.59
	Funk's D.	51.13	59.24	59.11	63.10	68.64
	Reid's D.F.	52.51	53.11	54.30	56.24	60.40
	Reid's D.	50.49	58.01	57.68	60.94	63.85

The diseased corn in 39 cases out of the forty absorbed more water than the disease-free corn. This fact may be more easily seen in the following table in which the average percentage water of imbibition is given for the disease-free and the diseased corn of both varieties, separately:

Table XII. Average water absorption by disease-free and diseased corn.

Variety	Condition	Average per cent water imbibed
Funk's Yellow Dent	Disease -free	46.04
Funk's Yellow Dent	Diseased	51.73
Reid's Yellow Dent	Disease-free	48.46
Reid's Yellow Dent	Diseased	51.76

The above figures suggest that the disease-free corn absorbs water less readily than diseased corn. If this is the case, the two diseased strains of corn are practically equal in regard to the diseased condition, but of the disease-free strains the Funk's Yellow Dent is the superior, since it absorbed less water under the same conditions than the companion strain of Reid's Yellow Dent.

In order to learn the influence of temperature on water absorption by diseased and disease-free corn, the imbibition percentages of both these strains were averaged.

Table XIII. Relation of Temperature to Imbibition in Diseased and Disease-free corn.

Temperature	Percentage Imbibition on water free basis by		Difference
	Diseased corn	Disease-free corn	
10	43.80	41.61	2.19
15	50.42	45.46	4.96
20	51.86	47.46	4.40
25	54.57	49.90	4.67
30	58.08	51.79	6.29

It will be noted that the absorption of water by diseased and disease-free corn is much more marked at 15° C than at 10° C. At 30° C there is another marked acceleration in the rate of water intake in the diseased corn. The disease-free corn is much more horny in composition than the diseased corn, which contains a high proportion of white starch. These results harmonize with the data obtained with the High and Low Protein varieties.

The disease-free kernels are heavier than those from the diseased ears. The average weight of the disease-free grains of the Funk's 90-day corn was .29 grams and that of the diseased kernels .26 grams. The kernels of the disease-free and diseased strains of Reid's Yellow Dent corn weighed .36 and .31 grams respectively.

The corn that was used in the imbibition studies, after removing the surface water, was taken immediately in covered jars to the field where it was planted on May 29. The corn representing each variety, condition and treatment was planted separately. Three grains were planted per hill by using the hand drop planter. The rows were fifteen hills long. Three check rows were planted, one on each side, and one in the center of the field. Only two of the check rows could be used, however, in calculating these data because the north row was badly damaged by gophers.

Notes on stand, sturdiness of plants, rate of growth, production of suckers, number of nubbins and good ears, occurrence of leaning and down plants, and development of smut, were taken during the season. Since the

data thus gathered do not show significant differences one way or the other for the time and temperature of presoaking of the seed, the tabulation of these is omitted from this paper.

It became necessary to destroy the Reid's Yellow Dent Corn in this experiment before pollination in order to preserve the purity of some valuable pure line corn growing near by.

The yield data of Funk's Ninety Day corn appear below in Table XIV.

Table XIV. Yield data of corn in the presoaking experiment.

Time soaking (hours)	Temperature	Disease-free		Diseased	
		Marketable	Unmarketable	Marketable	Unmarketable
None	Check	78.6	11.3	58.9	12.4
12	10	69.4	13.1	74.1	16.0
12	15	75.0	12.5	67.3	9.9
12	20	72.3	10.0	72.7	13.2
12	25	67.6	11.8	68.9	14.1
12	30	92.8	9.9	87.1	15.0
24	10	64.7	14.5	67.5	13.1
24	15	86.0	13.1	81.2	9.3
24	20	68.3	14.5	58.3	10.1
24	25	68.8	15.4	81.1	16.3
24	30	80.8	7.0	84.6	12.3
None	Check	81.4	15.5	73.2	17.2
36	10	99.8	12.2	62.7	13.1
36	15	75.2	15.4	77.6	12.2
36	20	84.0	12.8	56.7	10.0
36	25	75.9	10.0	78.6	13.1
36	30	83.2	10.9	61.5	14.3
48	10	74.9	8.1	89.4	8.1
48	15	87.6	6.2	57.3	10.0
48	20	66.0	9.1	81.9	12.9
48	25	85.3	7.0	78.0	8.0
48	30	26.2	7.1	61.0	8.0
Average		75.6	11.3	70.9	11.7

The average yield of the disease-free corn is almost five bushels in excess of the diseased corn. The soaking at various temperatures does not show consistent differences. The conclusion from this work can only be that pre-soaking seed corn has no effect, either beneficial or otherwise, on the performance of corn in the field under the conditions of the experiment. It is quite possible, however, that the condition of the soil as regards moisture content at the time of planting, may have an influence.

V. Conclusion

The data obtained in these investigations suggest that:

1. Corn harvested in the"milk"stage is capable of more rapid water absorption than either "dent" or "mature" corn. Its vitality and strength of germination however are less than those of more mature corn.

2. Kernels taken from the field when in the "dent" stage of development imbibe less water than those harvested in the "milk" stage and more than those that were completely mature. The rate of germination and viability is intermediate between those of the corn harvested in the early and late stages of development.

3. The initial moisture in corn is not the only factor that influences the quantity of water absorbed during a twenty-four hour period.

4. Corn containing 6 per cent moisture germinates much slower and possesses slightly lower vitality than that harvested in the"dent" stage. A moisture content of 12 per cent is more desirable for seed corn from the standpoint of vitality than 6 or 19, although corn of 19 per cent moisture germinates more quickly.

5. High Oil corn absorbs more water during a twenty-four hour period than Low Oil corn. It also germinates more rapidly and possesses greater viability than its low oil companion.

6. Low Protein corn imbibes water much more rapidly and begins the germinative process sooner than the High Protein

corn. Soon, however, it is overtaken by the High Protein type, which exceeds it in germinational vigor and vitality.

7. Water absorption by corn is very rapid during the first few hours of soaking. The rate of water intake gradually grows less, until some point quite beyond 29 hours.

8. Limited imbibition of water is not the only factor retarding germination at low temperatures. Water absorption at low temperatures is much more rapid in proportion to seedling growth than at high temperatures.

9. Diseased corn absorbs water more rapidly than that which is disease-free.

10. The soaking of seed corn in water at different temperatures for various periods has no apparent effect upon field growth and yield.

VI. Acknowledgements

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